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Memo

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From:	David Krizek
Title:	Copper World Project APP Facility BADCT Evaluation
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Subject:	Cost Analysis for BADCT Alternatives

1.0 FACILITIES LIST AND APP DESIGNATIONS

This memorandum provides supporting cost/benefit analyses for the selected Best Available Demonstrated Control Technology (BADCT) alternatives associated with the following facilities:

- Double-lined Ponds;
- Single-lined Ponds;
- Heap Leach Pad (HLP); and
- Tailings Storage Facility (TSF).

There are no alternatives associated with the Waste Rock Facility or the open pit areas; therefore, no cost/benefit analyses were prepared for these facilities.

Estimated potential leakage rates (PLRs) or seepage rates associated with the above facility types are presented in the technical memorandum prepared by Wood titled APP Facilities Discharge Calculations and BADCT Evaluation (dated September 1, 2022) (Wood, 2022a) or in the document titled Rosemont Copper World Project – TSF 1 and 2 Seepage Analysis Memorandum (dated June 24, 2022) (Wood, 2022b).

2.0 DOUBLE-LINED PROCESS SOLUTION PONDS

The double-lined process solution ponds include:

- Pregnant Leach Solution (PLS) Pond;
- Raffinate Pond;
- Reclaim Pond; and
- Primary Settling Pond (two cells).

The selected containment system for the double-lined process solution ponds will consist of the following components from bottom to top:

- Prepared subgrade;
- Underliner consisting of a geosynthetic clay liner (GCL) to achieve a hydraulic conductivity of less than $10E^{-6}$ cm/sec;
- An 80-mill high-density, polyethylene (HDPE) bottom liner;
- A leak collection and removal system (LCRS); and
- An 80-mil HDPE top liner.

The main difference between the selected option and the prescriptive BADCT liner configuration is the use of a GCL. The prescriptive design calls for 6-inches of compacted, low permeability soil (LPS), 3/8-inch minus material compacted to achieve a saturated hydraulic conductivity no greater than 10^{-6} cm/sec. The geosynthetic liner type was also changed to 80-mil HDPE instead of a 60-mil HDPE prescriptive liner. However, the liner type did not factor into the PLR calculation. A prepared subgrade would also be under the LPS.

Tables 1 through 4 show the cost comparison of using a LPS versus a GCL in the construction of the process solution ponds. The other components were considered equivalent and not considered in the cost comparison.

There is not an on-site LPS borrow source at the Copper World site. Therefore, the LPS cost was based on the following:

- Excavating, hauling, placing and compacting materials from an assumed suitable borrow source approximately 15 miles from the site. This cost is estimated at $15.66 per CY (RS Means Heavy Construction, 2020 Q2).
- Purchase of LPS from an offsite source. Estimated at $5.00 per CY (CDM Smith 2022 engineer's estimate). This is an estimate only. No off-site LPS source has been identified.
- Costs for characterizing, developing, closing and reclaiming a borrow source estimated at $1.77 per CY (RS Means Heavy Construction, 2020 Q2).

The GCL purchased/delivered and installed costs are estimated at $0.70 per square foot (sf) and $0.40 per sf, respectively. The GCL estimates are based on a phone estimate with Geoline (2022). The total purchased/delivered/installed cost was quoted at $1.10 per sf.

2.1 PLS Pond

The PLR of solution through the bottom liner for the prescriptive PLS Pond liner configuration was calculated at 27 gallons per year (Wood, 2022a).

The PLR of solution through the liner for the selected GCL alternative PLS Pond configuration was calculated at 0.54 gallons per year (Wood, 2022a).

The selected GCL alternative provides about a 98 percent reduction in the PLR.

Table 1 provides the cost differential of using a GCL versus a LPS underneath the bottom geosynthetic liner. The lined surface area (LSA) of the PLS Pond is 3.2 acres (139,392 acres).

Table 1: PLS Pond Differential Cost – GCL versus LPS

Material (units)	Quantity	Purchase		Placement		Total Cost
		Per Unit	Total	Per Unit	Total	
GCL (sf) (Selected)	153,331	$0.70	$107,332	$0.40	$61,332	$168,664
LPS (cy) (BADCT)	2,581	$5.00	$12,907	$17.43	$4,993	$57,899

Note: Liner (GCL) overlap was assumed using 110 percent of the LSA or 153,331 acres.

In summary, the GCL provides better engineering control (98 percent) but at higher cost to install. This assumes that the off-site LPS borrow material is available.

2.2 Raffinate Pond

The PLR of solution through the bottom liner for the prescriptive Raffinate Pond liner configuration was calculated at 13 gallons per year (Wood, 2022a).

The PLR of solution through the liner for the selected GCL alternative Raffinate Pond configuration was calculated at 0.25 gallons per year (Wood, 2022a).

The selected GCL alternative provides about a 98 percent reduction in the PLR.

Table 2 provides the cost differential of using a GCL versus a LPS underneath the bottom geosynthetic liner. The lined surface area (LSA) of the Raffinate Pond is 1.5 acres (65,340 sf).

Table 2: Raffinate Pond Differential Cost – GCL versus LPS

Material (units)	Quantity	Purchase		Placement		Total Cost
		Per Unit	Total	Per Unit	Total	
GCL (sf) (Selected)	71,874	$0.70	$50,312	$0.40	$28,750	$79,061
LPS (cy) (BADCT)	1,210	$5.00	$6,050	$17.43	$21,090	$27,140

Note: Liner (GCL) overlap was assumed using 110 percent of the LSA or 71,874 sf.

In summary, the GCL provides better engineering control (98 percent) but at higher cost to install. As noted, the cost differential assumes a source of LPS within 15 miles of the site. Source not confirmed.

2.3 Reclaim Pond

The PLR of solution through the bottom liner for the prescriptive Reclaim Pond liner configuration was calculated at 13 gallons per year (Wood, 2022a).

The PLR of solution through the liner for the selected GCL alternative Reclaim Pond configuration was calculated at 0.25 gallons per year (Wood, 2022a).

The selected GCL alternative provides about a 98 percent reduction in the PLR.

Table 3 provides the cost differential of using a GCL versus a LPS underneath the bottom geosynthetic liner. The lined surface area (LSA) of the Reclaim Pond is 1.5 acres (65,340 sf).

Table 3: Reclaim Pond Differential Cost – GCL versus LPS

Material (units)	Quantity	Purchase		Placement		Total Cost
		Per Unit	Total	Per Unit	Total	
GCL (sf) (Selected)	71,874	$0.70	$50,312	$0.40	$28,750	$79,061
LPS (cy) (BADCT)	1,210	$5.00	$6,050	$17.43	$21,090	$27,140

Note: Liner (GCL) overlap was assumed using 110 percent of the LSA or 71,874 sf.

In summary, the GCL provides better engineering control (98 percent) but at a higher cost to install. As noted, the cost differential assumes a source of LPS within 15 miles of the site. Source not confirmed.

2.4 Primary Settling Pond

The PLR of solution through the bottom liner for the prescriptive Primary Settling Pond liner configuration was calculated at 43 gallons per year (Wood, 2022a).

The PLR of solution through the liner for the selected GCL alternative Primary Settling Pond configuration was calculated at 0.85 gallons per year (Wood, 2022a).

The selected GCL alternative provides about a 98 percent reduction in the PLR.

Table 4 provides the cost differential of using a GCL versus a LPS underneath the bottom geosynthetic liner. The lined surface area (LSA) of the entire Primary Settling Pond is 5.1 acres. (222,156 sf). The pond consists of two cells: a main cell and a thickener cell that can be used emergency dumping of the tailings thickeners.

Table 4: Primary Setting Pond Differential Cost – GCL versus LPS

Material (units)	Quantity	Purchase		Placement		Total Cost
		Per Unit	Total	Per Unit	Total	
GCL (sf) (Selected)	244,372	$0.70	$171,060	$0.40	$97,749	$268,809
LPS (cy) (BADCT)	4,114	$5.00	$20,570	$17.43	$71,707	$92,277

Note: Liner (GCL) overlap was assumed using 110 percent of the LSA or 244,372 sf.

In summary, the GCL provides better engineering control (98 percent) but at higher cost to install. As noted, this assumes a source of LPS within 15 miles of the site. Source not confirmed.

3.0 SINGLE-LINED STORMWATER PONDS

The single-lined process solution ponds include:

- HLF North Stormwater Pond ;
- NLF South Stormwater Pond; and
- Process Area Stormwater Pond.

The selected containment system for the single-lined stormwater ponds will consist of the following components from bottom to top:

- Prepared subgrade;
- Underliner consisting of a geosynthetic clay liner (GCL) to achieve a hydraulic conductivity of less than $10E^{-6}$ cm/sec; and
- Geomembrane consisting of 80-mil, high-density polyethylene (HDPE).

The main difference between the selected option and the prescriptive BADCT liner configuration is the use of a GCL. The prescriptive design only calls for 6-inches of compacted subgrade material (3/8-inch minus material). The geosynthetic liner type was also changed to 80-mil HDPE instead of a 60-mil HDPE prescriptive liner. However, the liner type did not factor into the PLR calculation. A prepared subgrade would also be under the screened and compacted 6-inch layer.

Tables 5 through 7 show the cost comparison of using a 6-inch screened, compacted layer versus a GCL in the construction of the stormwater ponds. The other components were considered equivalent and not considered in the cost comparison.

It is assumed that on-site borrow material will be screened and used as the 6-inch compacted layer. Therefore, the screened and compacted layer cost was based on the following:

- Excavating, hauling, placing and compacting materials from an assumed suitable borrow source approximately 0.5 mile from the point of use. This cost is estimated at $3.54 per CY (RS Means Heavy Construction, 2020 Q2).
- Characterizing, excavating and screening from a suitable borrow source within 0.5 mile of the point of use. This cost is estimated at $1.77 per CY (RS Means Heavy Construction, 2020 Q2).

The GCL purchased/delivered and installed costs are estimated at $0.70 per square foot (sf) and $0.40 per sf, respectively. The GCL estimates are based on a phone estimate with Geoline (2022). The total purchased/delivered/installed cost was quoted at $1.10 per sf.

3.1 HLF North Stormwater Pond

The PLR of solution through the liner for the prescriptive HLF North Stormwater Pond liner configuration was calculated at 157 gallons per day (Wood, 2022a).

The PLR of solution through the liner for the GCL alternative was calculated at 39 gallons per day (Wood, 2022a).

The selected GCL alternative provides about a 75 percent reduction in the PLR. Note that the lined stormwater ponds are normally dry in anticipation of storm events.

Table 5 provides the cost differential of using a GCL underneath the geosynthetic liner versus a screened, compacted 6-inch layer underneath the liner. The lined surface area (LSA) of the HLF North Stormwater Pond is assumed to be 3.0 acres (130,680 sf).

Table 5: HLF North Stormwater Pond Differential Cost – GCL versus Compacted Layer

Material (units)	Quantity	Purchase		Placement		Total Cost
		Per Unit	Total	Per Unit	Total	
GCL (sf) (Selected)	143,748	$0.70	$100,624	$0.30	$43,124	$143,748
Screened/compacted (cy) (BADCT)	2,420	$0.00	$0	$5.31	$12,850	$12,850

Note: Liner (GCL) overlap was assumed using 110 percent of the LSA or 143,748 sf.

In summary, the GCL provides better engineering control (75 percent) but at a higher cost to install.

3.2 HLF South Stormwater Pond

The PLR of solution through the liner for the prescriptive HLF South Stormwater Pond liner configuration was calculated at 157 gallons per day (Wood, 2022a).

The PLR of solution through the liner for the GCL alternative was calculated at 39 gallons per day (Wood, 2022a).

The selected GCL alternative provides about a 75 percent reduction in the PLR. Note that the lined stormwater ponds are normally dry in anticipation of storm events.

Table 6 provides the cost differential of using a GCL underneath the geosynthetic liner versus a screened, compacted 6-inch layer underneath the liner. The lined surface area (LSA) of the HLF South Stormwater Pond is assumed to be 3.0 acres (130,680 sf).

Table 6: HLF South Stormwater Pond Differential Cost – GCL versus Compacted Layer

Material (units)	Quantity	Purchase		Placement		Total Cost
		Per Unit	Total	Per Unit	Total	
GCL (sf) (Selected)	143,748	$0.70	$100,624	$0.30	$43,124	$143,748
Screened/compacted (cy) (BADCT)	2,420	$0	$0	$5.31	$12,850	$12,850

Note: Liner (GCL) overlap was assumed using 110 percent of the LSA or 143,748 sf.

In summary, the GCL provides better engineering control (75 percent) but at a higher cost to install.

3.3 Process Area Stormwater Pond

The PLR of solution through the liner for the prescriptive Process Area Stormwater Pond liner configuration was calculated at 77 gallons per day (Wood, 2022a).

The PLR of solution through the liner for the GCL alternative was calculated at 19 gallons per day (Wood, 2022a).

The selected GCL alternative provides about a 75 percent reduction in the PLR. Note that the lined stormwater ponds are normally dry in anticipation of storm events.

Table 7 provides the cost differential of using a GCL underneath the geosynthetic liner versus a screened, compacted 6-inch layer underneath the liner. The lined surface Area (LSA) of the Process Area Stormwater Pond is assumed to be 1.5 acres (65,340 sf).

Table 7: Stormwater Pond Differential Cost – GCL versus Compacted Layer

Material (units)	Quantity	Delivered/Prepared		Placement		Total Cost
		Per Unit	Total	Per Unit	Total	
GCL (sf) (Selected)	71,874	$0.70	$50,312	$0.30	$21,562	$71,874
Screened/compacted (cy) (BADCT)	1,210	$0	$0	$5.31	$6,425	$6,425

Note: Liner (GCL) overlap was assumed using 110 percent of the LSA or 71,874 sf.

In summary, the GCL provides better engineering control (75 percent) but at a higher cost to install.

4.0 HEAP LEACH PAD (HLP)

The selected liner system for the Heap Leach Pad (HLP) will consist of the following components from bottom to top:

- Prepared subgrade;
- Underliner consisting of a geosynthetic clay liner (GCL) to achieve a hydraulic conductivity of less than $10E^{-6}$ cm/sec;
- Geomembrane consisting of 80-mil, double-sided textured linear low-density polyethylene (LLDPE); and
- Overliner consisting of a three-foot thick layer of a well-draining material installed over the geomembrane. The overliner material will consist of 1.5-inch minus rock with a hydraulic conductivity of $1x10^{-1}$ cm/sec or higher. There will also be a series of perforated solution collection pipes directly above the geomembrane which will be sized and spaced to allow an average and maximum hydraulic head over the liner of less than 2 feet and 5 feet, respectively.

The main difference between the selected option and the prescriptive BADCT liner configuration is the use of a GCL instead of a 12-inch layer of low permeability soil (LPS) having a hydraulic conductivity of less than $10E^{-6}$ cm/sec. The geosynthetic liner type was also changed to an 80-mil LLDPE instead of a 60-mil HDPE prescriptive liner. However, the liner type did not factor into the potential leakage rate (PLR) calculation presented the technical memorandum prepared by Wood tilted APP Facilities Discharge Calculations and BADCT Evaluation (dated September 1, 2022) (Wood, 2022a). A prepared subgrade would also be under the LPS.

Table 8 shows the cost comparison of using a LPS versus a GCL in the construction of the HLP. The other components were considered equivalent and not considered in the cost comparison.

There is not an on-site LPS borrow source at the Copper World site. Therefore, the LPS cost was based on the following:

- Excavating, hauling, placing and compacting materials from an assumed suitable borrow source approximately 15 miles from the site. This cost is estimated at $15.66 per CY (RS Means Heavy Construction, 2020 Q2).
- Purchase of LPS from an offsite source. Estimated at $5.00 per CY (CDM Smith 2022 engineer's estimate). This is an estimate only. No off-site LPS source has been identified.
- Costs for characterizing, developing, closing and reclaiming a borrow source estimated at $1.77 per CY (RS Means Heavy Construction, 2020 Q2).

The GCL purchased/delivered and installed costs are estimated at $0.70 per square foot (sf) and $0.40 per sf, respectively. The GCL estimates are based on a phone estimate with Geoline (2022). The total purchased/delivered/installed cost was quoted at $1.10 per sf.

4.1 Heap Leach Pad (HLP)

The PLR of solution through the liner for the prescriptive HLP liner configuration was calculated at 492 gallons per day.

The PLR of solution through the liner for the GCL alternative was calculated at 78 gallons per day.

The selected GCL alternative provides about an 84 percent reduction in the PLR.

Table 8 provides the cost differential of using a GCL versus a LPS underneath the geosynthetic liner. The lined surface area (LSA) of the HLP is assumed to be 336 acres (14,636,160 sf).

Table 8: Heap Leach Pad Differential Cost – GCL versus LPS

Material (units)	Quantity	Delivered		Placement		Total Cost
		Per Unit	Total	Per Unit	Total	
GCL (sf) (Selected)	16,099,776	$0.70	$11,269,843	$0.40	$6,439,910	$17,709,754
LPS (cy) (BADCT)	542,080	$15.66	$8,488,973	$6.77	$3,669,882	$12,158,854

Note: Liner (GCL) overlap was assumed using 110 percent of the LSA or 16,099,776 sf.

In summary, the GCL provides better engineering control (84 percent) bit at a higher cost to install. As noted, the cost differential assumes a source of LPS within 15 miles of the site. Source not confirmed.

5.0 TAILINGS STORAGE FACILITY (TSF)

The following alternatives were compared in Wood (2022a) with regard to comparing the potential for seepage to reach groundwater:

- Alternative 1: No liner, no underdrains (i.e., no seepage collection underneath the tailings);
- Alternative 2: Underdrain system (i.e., installation of a seepage collection system underneath the tailings); and

- Alternative 3: Geomembrane liner system.

Alternative 2 is the selected BADCT design of the Tailings Storage Facilities (TSFs) includes the following components:

- Prepared subgrade (roller compacted);
- Seepage collection system consisting of a network of perforated pipes enveloped in gravel and filter sand or geofabric.
- Seepage from the collection system routed to seepage collection trenches where the solution is pumped back into the process circuit. The seepage collection trenches are also designed to intersect seepage at the bedrock contact around the perimeter of the TSFs.

Potential discharge from the TSFs was presented in Wood (2022a) using the Darcy equation for the three alternatives. These discharge estimates were for comparative purposes only. The results are summarized below:

- Alternative 1: 759 gpm for TSF-1 and 377 gpm for TSF-2;
- Alternative 2: 159 gpm for TSF-1 and 75 gpm for TSF-2; and
- Alternative 3: 0.32 gpm for TSF-1 and 0.11 gpm for TSF-2.

The effectiveness of the seepage collection system in Alternative 2 was assumed to be 80 percent for the analysis presented in Wood (202a). However, in addition to the analysis presented in Wood (2022a) using the Darcy equation, an additional analysis was performed for the TSFs for Alternative 2 using a 2-D seepage model (SLIDE2 version 2021 (Rocscience, 2021). The results indicate that the volume of solution bypassing the seepage collection system would be 11.0 gpm for TSF-1 and 6.4 gpm for TSF-2 (Wood, 2022b).

The main difference between the selected option and the prescriptive BADCT liner configuration is the use of a 12-inch layer of low permeability soil (LPS) having a hydraulic conductivity of less than $10E^{-6}$ cm/sec along with a geosynthetic liner (60-mil HDPE). It is assumed for the purposes of this cost comparison that the cost of constructing the seepage collection system (including trenches) is equivalent to constructing the overliner drainage system required above the geomembrane in the prescriptive approach. Therefore, the cost differential is the cost of the geomembrane liner (60-mil) along with the 12-inch layer of LPS.

Tables 9 and 10 shows the cost of installing the 60-mil geomembrane over 12-inches of LPS for TSF-1 and TSF-2, respectively

There is not an on-site LPS borrow source at the Copper World site. Therefore, the LPS cost was based on the following:

- Excavating, hauling, placing and compacting materials from an assumed suitable borrow source approximately 15 miles from the site. This cost is estimated at $15.66 per CY (RS Means Heavy Construction, 2020 Q2).
- Purchase of LPS from an offsite source. Estimated at $5.00 per CY (CDM Smith 2022 engineer's estimate). This is an estimate only. No off-site LPS source has been identified.
- Costs for characterizing, developing, closing and reclaiming a borrow source estimated at $1.77 per CY (RS Means Heavy Construction, 2020 Q2).

The 60-mil (HDPE) geomembrane purchased/delivered and installed costs are estimated at $0.57 per square foot (sf) and $1.98 per sf, respectively. The geomembrane estimates are based on RS Means Heavy Construction (2020 Q2).

The lined surface area (or LSA) of TSF-1 is assumed to be 946 acres (41,207,760 sf).

The lined surface area (or LSA) of TSF-2 is assumed to be 307 acres (13,372,920 sf).

Table 9: TSF-1 Liner Cost – Geomembrane and LPS (BADCT Liner system)

Material (units)	Quantity	Delivered		Placement		Total Cost
		Per Unit	Total	Per Unit	Total	
HDPE (sf)	45,328,536	$0.40	$18,131,414	$0.30	$13,598,561	$31,729,975
LPS (cy)	1,526,213	$24.00	$36,629,120	$7.00	$10,683,493	$47,312,613
					Total	$79,042,589

Note: Liner (60-mil HDPE geomembrane) overlap was assumed 110 percent of the LSA or 45,328,536 sf.

Table 10: TSF-2 Liner Cost – Geomembrane and LPS (BADCT Liner system)

Material (units)	Quantity	Delivered		Placement		Total Cost
		Per Unit	Total	Per Unit	Total	
HDPE (sf)	14,710,212	$0.40	$5,884,085	$0.30	$4,413,064	$10,297,148
LPS (cy)	495,293	$24.00	$11,887,040	$7.00	$3,467,053	$15,354,093
					Total	$25,651,242

Note: Liner (60-mil HDPE geomembrane) overlap was assumed 110 percent of the LSA or 14,710,212 sf.

In summary, the prescriptive approach increases the cost of the Copper World project by about $200,0000. As noted above, the volume of solution potentially bypassing the seepage collection system (selected approach) would be 11.0 gpm for TSF-1 and 6.4 gpm for TSF-2. Although the estimated potential leakage rate (PLR) through the geomembrane was estimated at 0.32 gpm for TSF-1 and 0.11 gpm for TSF-2, the cost of implementation is not warranted based on the anticipated efficiency of the seepage collection system.

As an alternative to the LPS layer, **Tables 11 and 12** show the costs of using a GCL under the geomembrane. In this case, the cost differential is about $20 million more. As noted, the cost assumes a source of LPS can be secured within 15 miles of the site. Source not confirmed.

Additionally, the GCL purchased/delivered and installed costs are estimated at $0.70 per square foot (sf) and $0.40 per sf, respectively. The GCL estimates are based on a phone estimate with Geoline (2022). The total purchased/delivered/installed cost was quoted at $1.10 per sf.

Table 11: TSF-1 Liner Cost – Geomembrane and GCL

Material (units)	Quantity	Delivered		Placement		Total Cost
		Per Unit	Total	Per Unit	Total	
HDPE (sf)	45,328,536	$0.57	$25,837,266	$1.98	$89,750,501	$115,587,767
GCL (sf)	45,328,536	$0.70	$31,729,975	$0.40	$18,131,414	$49,861,390
					Total	$165,449,156

Note: Liner and GCL overlap was assumed using 110 percent of the LSA.

Table 12: TSF-2 Liner Cost – Geomembrane and GCL

Material (units)	Quantity	Delivered		Placement		Total Cost
		Per Unit	Total	Per Unit	Total	
HDPE (sf)	14,710,212	$0.57	$8,384,821	$1.98	$29,126,220	$37,511,041
GCL (sf)	14,710,212	$0.70	$10,297,148	$0.40	$5,844,085	$16,181,233
					Total	$53,692,274

Note: Liner and GCL overlap was assumed using 110 percent of the LSA

6.0 REFERENCES

Wood, 2022a. APP Facilities Discharge Calculations and BADCT Evaluation (dated September 1, 2022)

Wood, 2022b. Rosemont Copper World Project – TSF 1 and 2 Seepage Analysis Memorandum (dated June 24, 2022)